A Bibliography of the Biological Oceanography of the Strait of Georgia and Adjacent Inlets, with Emphasis on Ecological Aspects

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Fisheries and Aquatic Sciences No. 1293

July 1984

A BIBLIOGRAPHY OF THE BIOLOGICAL OCEANOGRAPHY OF THE STRAIT OF GEORGIA AND ADJACENT INLETS, WITH EMPHASIS ON ECOLOGICAL ASPECTS

by

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ABSTRACT

Harrison, P. J., J. D. Fulton, G. Miller, C. D. Levings, F. J. R. Taylor, T. R. Parsons, P. A. Thompson, and D. W. Mitchell. 1984. A bibliography of the biological oceanography of the Strait of Georgia and adjacent inlets, with emphasis on ecological aspects. Can. Tech. Rep. Fish. Aquat. Sci. No. 1293: 140 p.

This preliminary bibliography contains published and unpublished reports on the biological oceanography of the Strait of Georgia and associated inlets. Ecological aspects of the fauna and flora of the pelagic and benthic environments are emphasized and only limited reference is made to taxonomic studies. Studies conducted in large experimental enclosures (mesocosms) located in Saanich Inlet during the 1970s by a National Science Foundation project, called CEPEX (controlled ecosystem pollution/population experiment) are also included. Each reference contains key words. These key words are arranged in a subject index and they are keyed to references by numbers.

Key words: bibliography, Strait of Georgia, biological oceanography, British Columbia inlets, ecology, phytoplankton, zooplankton, bacteria, food web.

RÉSUMÉ

Harrison, P. J., J. D. Fulton, G. Miller, C. D. Levings, F. J. R. Taylor, T. R. Parsons, P. A. Thompson, and D. W. Mitchell. 1984. A bibliography of the biological oceanography of the Strait of Georgia and adjacent inlets, with emphasis on ecological aspects. Can. Tech. Rep. Fish. Aquat. Sci. No. 1293: 140 p.

Cette bibliographie préliminaire donne la list des rapports publiés et inédits traitant de l'océanographie biologique dans le détroit de Géorgie et les inlets annexes. On y souligne les aspects écologiques de la faune et de la flore des environnements pélagique et benthique, les études taxonomiques n'y étant traitées que de façon superficielle. Des études effectuées au cours des années 1970 dans le cadre du projet EPEP (Expérience sur la pollution en écosystème contrôlé) de la National Science Foundation et portant sur de grandes enceintes expérimentales (mésocosmes) situées dans l'inlet Saanich sont aussi présentées. Chaque référence bibliographique est accompagnée de mots clés. Ces mots clés sont présentés sous forme d'un index des sujets et des nombres permettent le renvoi aux références.

Mots clés: bibliographie, détroit de Géorgie, océanographie biologique, inlets de la Colombie-Britannique, écologie, phytoplancton, zooplancton, bactérie, chaîne alimentaire.

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INTRODUCTION

The Strait of Georgia is a partly enclosed basin on the west coast of Canada lying between the mountainous coast range of the mainland of British Columbia and the southern half of Vancouver Island. The strait comprises an area of 6,900 km^2. There are six well-developed inlets associated with the Strait of Georgia, Saanich Inlet, Burrard Inlet (composed of Vancouver Harbour, Indian Arm, and Port Moody Arm), Howe Sound, Jervis Inlet, Desolation and Pendrell Sounds and Bute Inlet. (Fig. 1). It is a valuable fishery and rearing area for the young of several major stocks of Pacific salmon and for large stocks of herring. Therefore, it is important to have a comprehensive understanding of the biological oceanography of this economically important area.

In 1982, a "Symposium on the Oceanography of the Strait of Georgia" was held in Nanaimo, B.C. This symposium summarized the physical (LeBlond 1983), geological (Luternauer *et al.* 1983), biological (Harrison *et al.* 1983; Levings *et al.* 1983), fisheries (Ketchen *et al.* 1983), and pollution (Waldichuk 1983) studies of the Strait. These summaries are published in Canadian Journal of Fisheries and Aquatic Science, Volume 40(7), 1983.

SCOPE

This preliminary bibliography provides a list of published and unpublished (data reports, theses, etc.) reports through to 1982, describing the biological oceanography and biological resources of the Strait of Georgia and associated inlets. Each reference contains subject key words which are arranged by categories (e.g. species, geographic and ecological regions, etc.) in a subject index and keyed back to references by numbers.

Both the pelagic and benthic environments and associated organisms numbers are included in this bibliography. References associated with planktonic microalgae (phytoplankton), benthic microalgae, macroalgae (macrophytes or seaweeds), bacteria, zooplankton and benthic invertebrates and primary and secondary production levels are emphasized. Most of the references from the National Science Foundation funded CEPEX (Controlled Ecosystem Pollution Experiment) project conducted in Saanich Inlet from 1972- 82 have been included since they were related to food chain dynamics of that area. Only limited coverage has been given to fish, because they have been the subject of a bibliography by McInnes, Nash and Godfrey (1974) and a review by Ketchen, Bourne and Butler (1983). Restricted coverage in the form of only a few key references, has been given to areas adjacent to the Strait of Georgia, such as Puget Sound, Queen Charlotte Sound, Knight Inlet, Juan de Fuca Strait and the west coast of Vancouver Island.

This bibliography is intended to complement existing bibliographic coverage of the Strait of Georgia, such as the bibliographies found in the Special Estuary Series published by the Department of the Environment which emphasis nearshore aspects (see the following section for a complete listing). Detailed bibliographies have also been prepared for Puget Sound, an area adjacent to the southern part of the strait (McLellan 1953a,b, 1954; Collias and Duxbury 1974; Collins and Andreeva 1977).

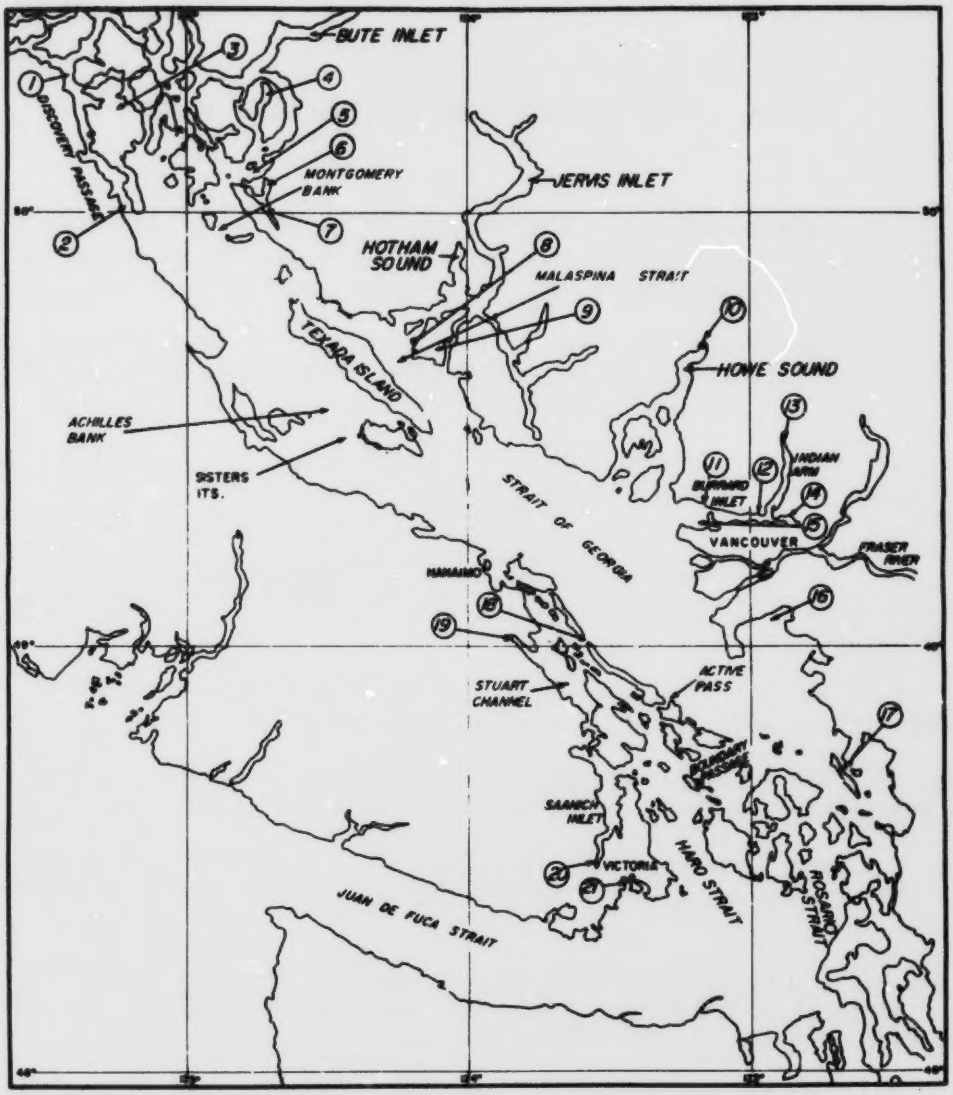
BUTE INLET
1
DISCOVERY PASSAGE
2
3
4
5
6
7
MONTGOMERY BANK
JERVIS INLET
HOTHAM SOUND
8
MALASPINA STRAIT
9
10
TEXADA ISLAND
HOWE SOUND
ACHILLES BANK
SISTERS ITS.
13
11
12
BURRARD INLET
INDIAN ARM
14
15
STRAIT OF GEORGIA
VANCOUVER
FRASER RIVER
NANAIMO
18
19
16
STUART CHANNEL
ACTIVE PASS
17
BOUNDARY PASSAGE
SAANICH INLET
VICTORIA
20
21
HARO STRAIT
ROSARIO STRAIT
JUAN DE FUCA STRAIT

FIG. 1. The Strait of Georgia and contiguous waters. Geographical locations referred to in the text and references are indicated by numbers. 1, Johnstone Strait; 2, Seymour Narrows; 3, Quadra Island; 4, Pendrell Sound; 5, Desolation Sound; 6, Theodosia Inlet; 7, Malaspina Inlet; 8, Hidden Basin; 9, Nelson Island; 10, Squamish River; 11, Capilano River; 12, Seymour River; 13, Indian River; 14, Port Moody Arm; 15, English Bay; 16, Boundary Bay; 17, Lummi Island; 18, Porlier Pass; 19, Ladysmith Harbour; 20, Goldstream River; 21, Esquimalt Lagoon. Beyond the chart to the north are the following: Dixon Entrance (north of Queen Charlotte Sound (northern end of Vancouver Island), Forward Harbour (off central Johnstone Strait), Knight Inlet (off central Johnstone Strait).

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CEPEX, zooplankton, copper, toxicity, growth

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CEPEX, zooplankton, copepods, development stages, life history

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euphausiids, ecology, distribution, respiration, temperature, salinity, stress

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euphausiids, distribution, temperature, salinity, respiration, stress, seasonal effects, latitudinal effects

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CEPEX, bacteria, heterotrophic production, pollution, toxicity, heavy metals

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primary production, fjord, Indian Arm, phytoplankton, nutrients, temperature, salinity, oxygen

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primary production, fjord, Indian Arm, phytoplankton, nutrients, temperature, salinity, oxygen

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shellfish, mariculture, economics, Gulf Islands

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turbidity, inlets

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physical oceanography, Squamish River estuary, salinity, currents

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Nanaimo River estuary, sewage, physical oceanography

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currents, physical oceanography

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Departure Bay, Hammond Bay, *Oncorhynchus*, larvae, fish, feeding, rations, bahavior, distribution, pink salmon

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CEPEX, phytoplankton, copper, silicate, toxicity, growth

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Oyster River estuary, *Oncorhynchus*, juveniles, fish, feeding, environmental impact, intertidal

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Squamish River estuary, *Oncorhynchus*, juveniles, fish, feeding, environmental impact, intertidal

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Campbell River estuary, Oncorhynchus, juveniles, fish, feeding, environmental impact, intertidal

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CEPEX, food chains, review, phytoplankton, zooplankton, bacteria, primary production, grazing, nutrients, secondary production, vertical mixing, diatoms

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CEPEX, heavy metals, toxicity, food chains, review

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CEPEX, zooplankton, heavy metals, toxicity, growth

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nitrogen, nitrate, ammonium, organic nitrogen, phytoplankton, zooplankton, excretion, Saanich Inlet

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shorelines, vegetation, Nanoose Bay, Gulf Islands

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shorelines, vegetation, herring spawn, Stuart Channel

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heavy metals, Howe Sound, pollution, bivalves, fishes

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heavy metals, pollution, inlets

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pelagic-benthic transfer, sedimentation, pycnocline

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CEPEX, *Calanus*, *Pseudocalanus*, copepods, feeding, behavior, grazing, herbivore

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Fraser River estuary, Sturgeon Bank, intertidal, harpacticoids, copepods, sediments, community

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eelgrass, *Zostera*, distribution, population ecology, intertidal, Boundary Bay

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decomposition, eelgrass, macroalgae, amphipods, grazing, bacteria

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photosynthesis, eelgrass, *Zostera*, organic compounds

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CEPEX, phytoplankton, nutrients, irradiance, grazing growth, diatoms, review, species diversity

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nitrogen, ammonium, excretion, decomposition, bacteria grazing, CEPEX

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CEPEX, phosphate, plankton, phytoplankton, bacteria, nutrients

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CEPEX, nitrogen, phytoplankton, copper, toxicity, trace metals

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keys, taxonomy, shrimps

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herring, feeding habits, Oncorhynchus

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detritus, juveniles, Oncorhynchus, Nanaimo River estuary, chum salmon, feeding, growth, food habits

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Oncorhynchus, estuary, life history, juveniles, fish, review

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euphausiids, population ecology, Saanich Inlet, Jervis Inlet, growth, mortality, biomass, feeding, reproduction, fishery, economics, chemical composition

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temperature, salinity, oxygen, deep water renewal, Saanich Inlet

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temperature, salinity, oxygen, deep water renewal

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temperature, Jervis Inlet

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temperature, salinity, oxygen, deep water renewal, Saanich Inlet

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physical oceanography, Nanoose Bay, survey, water chemistry, plankton

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temperature, salinity, oxygen, Johnstone Strait

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sewage, Iona Island, toxicity, pollution, nutrients

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reproduction, phytoplankton, Howe Sound, Burrard Inlet, chitons, Tonicella

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polychaetes, taxonomy, keys

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phytoplankton, primary production, nutrients, Saanich Inlet, irradiance, chlorophyll, grazing, photosynthesis

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primary production, North Pacific, review, phytoplankton, nutrients, irradiance, light limitation, chlorophyll, photosynthesis

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seasonal effects, photosynthesis, phytoplankton, Saanich Inlet, nutrients, irradiance, chlorophyll, primary production

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CEPEX, bacteria, hydrocarbons, growth, heterotrophic production

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CEPEX, amino acid, phytoplankton, bacteria, organic nitrogen, decomposition

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CEPEX, heavy metals, toxicity, phytoplankton, diatoms, amino acid

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CEPEX, resting spores, *Chaetoceros*, diatoms, germination, nitrogen, temperature

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temperature, physical oceanography

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salinity, physical oceanography

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salinity, temperature, physical oceanography

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temperature, salinity, physical oceanography

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temperature, salinity, physical oceanography

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review, bibliography, Fraser River estuary

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review, bibliography, Squamish River estuary

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CEPEX, zooplankton, feeding, respiration, copepods

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CEPEX, juveniles, *Oncorhynchus*, growth

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CEPEX, heavy metals, toxicity, bacteria, nitrogen, nutrients

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shellfish, mariculture, economics, Qualicum River estuary

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environmental impact, Nanaimo River estuary

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CEPEX, zooplankton, decomposition, hydrocarbons, toxicity, growth

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zooplankton, biomass, distribution, temperature, salinity

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Anisogammarus, Fraser River estuary, currents, benthic invertebrates

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submersible, benthic invertebrates, survey, Howe Sound

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benthic invertebrates, subtidal zone, macro-invertebrates

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shellfish, toxicity, irradiance

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Stuart Channel, pollution, toxicity, currents

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pollution, toxicity, currents, temperature, salinity

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review, pollution, toxicity, organic compounds, sewage, pulp mills, heavy metals

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salinity, estuary, Fraser River estuary

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winter, physical oceanography, Baynes Sound, survey

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CEPEX, trace metals, heavy metals, copper, carbon, chelating agents

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nanoflagellates, winter, Saanich Inlet, irradiance, light limitation, temperature, nutrients, phytoplankton, diatoms, dinoflagellate, growth, photosynthesis

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red water bloom, dinoflagellate, growth, irradiance, nutrients, distribution

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chlorophyll, distribution, phytoplankton, physical oceanography, Fraser River plume

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chlorophyll, distribution, phytoplankton, physical oceanography, Fraser River plume

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physical oceanography, Puget Sound, San Juan Archipelago, water chemistry, ecology, plankton

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physical oceanography, survey, water chemistry, ecology, plankton

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sedimentation, sediments, pollution

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predation, larvae, herring, *Clupea*, amphipods, *Hyperoche*

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trawl survey, fish, survey

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wood borers, reproduction, seasonal effects

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seasonal effects, physical oceanography, Indian Arm, copepods, *Euchaeta*, distribution, growth, water chemistry

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trace metals, copepods, fjord, ultraviolet light, chelating agents, toxicity, copper, Euchaeta

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water chemistry, Fraser River estuary, salinity

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survey, distribution, macroalgae, intertidal, salinity, wave action

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Departure Bay, Berkeley Creek, plankton, estuary, macro-invertebrates

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CEPEX, zooplankton, distribution

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CEPEX, plankton, bacteria, heterotrophic production, review, food chains, respiration, phytoplankton, decomposition

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copepods, parasitism, Nanaimo River estuary

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phytoplankton, spring bloom, Puget Sound, fjord, mathematical models, nutrients, irradiance, chlorophyll, grazing

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copepods, *Calanus*, taxonomy, distributions, population ecology, water properties

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Balanus, barnacle, intertidal, shorelines, energy budget, Burrard Inlet

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Balanus, barnacle, transplant experiments, survival, fecundity, growth, Squamish River estuary, salinity, turbidity

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temperature, salinity, currents, reproduction, distribution, *Littorina*, intertidal

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intertidal, marshes, Fraser River estuary, community, primary production

LIST OF KEY WORDS

Species

a) INVERTEBRATES

Aequorea
Aegina
Aglantha
amphipods
Anisogammarus
Aurelia
Balanus
barnacle
benthic invertebrates
bivalves
Bolinopsis
Bradyidius
Brisaster
Calanus
Callianassa
Cancer
chaetognaths
Chiridota
chitons
ciliate
Cladocera
clam
Clinocardium
coelenterate
copepods
Corophium
crab
Crassostrea
ctenophores
Cyphocaris
Dendraster
Eogammarus
Euchaeta
Eukrohnia
euphausiids
Eutonina
foraminifera
gastropods
harpacticoids
herbivore
hydroid
hydromedusae
Hyperoche
isopod
invertebrates
Littorina
Lycodopsis
Macoma
macro-invertebrates
meiofauna
meroplankton
Mesodinium
microzooplankton
Mnemiopsis
Mollusca
nauplii
Neocalanus
Neomysis
Oithona
Oikopleura
oligochaetes
Orchomene
ostracods
oysters
Paracalanus
Pasiphaea
Phialidium
Pleurobrachia
polychaetes
Pseudocalanus
Sagitta
Sarsia
shellfish
shrimps
Strongylocentrotus
Thysanoessa
tintinnid
Tonicella
wood borers
zooplankton

b) MARSH PLANTS

Agrostis
Carex
Distichlis
eelgrass
Festuca
Menyanthes
Potentilla
Scirpus
Trichlochia
Typha
Upogebia
Zostera

c) MACROALGAE

Fucus
kelp
Laminariales
macroalgae
Macrocystis
Nereocystis
Phaeophyta
red algae

d) PHYTOPLANKTON

algae
Chaetoceros
diatoms
dinoflagellate
Gonyaulax
Micromonas
nanoflagellates
phytoplankton
Skeletonema
Thalassiosira

e) FISH

Anoplarchus
chinook salmon
chum salmon
Clupea
coho salmon
fish
fish stocks
herring
herring spawn
myctophids
Oncorhynchus
pink salmon
sockeye salmon

f) OTHERS

bacteria
fungi
juveniles
larvae
microbenthic algae
microorganisms
plankton
vegetation
virus

Geographic/Ecological Regions

Bath Island
Baynes Sound
Berkeley Creek
Big Qualicum estuary
Boundary Bay
Bowen Island
Burrard Inlet
Bute Inlet
Campbell River estuary
Canoe Pass
CEPEX
Coffin Island
Comox Harbour
Courtenay River estuary
Cowichan River estuary
Departure Bay
epibenthos
estuary
fjord
Flat Top Islands
Fraser River
Fraser River estuary
Fraser River plume
Friday Harbor
Gulf Islands
Hammond Bay
Hotham Sound
Howe Sound
Indian Arm
inlets
intertidal
Iona Island
Jervis Inlet
Johnstone Strait
Juan de Fuca Strait
Knight Inlet
Ladysmith Harbour
Lymn Creek estuary
McCartney Creek estuary
Malaspina Strait
marshes
mudflats
Nanaimo River
Nanaimo River estuary
Nanoose Bay
North Pacific
Oyster River estuary
Pendrell Sound
Point Grey
Princess Louisa Inlet
Puget Sound
Qualicum River estuary
Queen Charlotte Islands
Roberts Bank
Saanich Inlet
Saltspring Island
Samsun Narrows
sand
sand flats
San Juan Archipelago
Satellite Channel
Sear Island
sediments
shorelines
Squamish River estuary
Stuart Channel
Sturgeon Bank
submersible
subtidal zone
Thornborough Channel
tidal flat
Vancouver
Vancouver Harbour
Vancouver Island
Woodward Island

Ecological Events & Processes

advection
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ammonium
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chelating agents
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cysts
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deep water renewal
detritus
development
diel migration
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ultraviolet light
vegetation
vertical distribution
vertical mixing
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wave action
winter
zinc
zonation

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keys
mathematical models
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statistics
submersible
survey
taxonomy
transect
transplant experiments
trawl survey

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statistics
toxicity

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